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DESIGN AND OPERATION OF AN EXERCISE DEVICE FOR SUBHUMAN PRIMATES

C. R. Curran
W. R. Wiegel
D. N. Stevens

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Nuclear Agency
Bethesda, Maryland

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13. ABSTRACT

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C. R. CURRAN
W. R. WIEGEL
D. N. STEVENS

W. F. Davis, Jr.
W. F. DAVIS, JR.
Chairman
Behavioral Sciences Department

Myron I. Varon
MYRON I. VARON
Captain MC USN
Director

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE
Defense Nuclear Agency
Bethesda, Maryland

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ABSTRACT

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I. INTRODUCTION

Although exercise devices for laboratory animals such as rats, mice and dogs have been described along with their advantages and disadvantages,[1,2,4] an apparatus suitable for the automatic exercising of primates has not previously been reported. The purpose of this report is to describe the materials and design used to construct a primate physical exercise apparatus, to describe simple training procedures, and to present an illustrative exercise record. The apparatus was specifically designed to generate uniform levels of physical exercise or exercise stress without resorting to a motor-driven system. It is currently used in this laboratory to study the response of exercised primates prior to and following exposure to high doses of ionizing radiation.

II. OPERATIONAL CHARACTERISTICS

With this instrument an animal's exercise level can be maintained using behavioral paradigms such as free-operant (Sidman) avoidance[3] with or without exteroceptive cues. The exercise rate and predetermined exercise session length can be varied within broad limits. To date, primates (Macaca mulatta) have been exercised at steady rates, as measured on a tachometer, up to 4 miles per hour for successive 10-minute sessions separated by 5-minute rest periods in daily 100-minute exercise periods. Training a primate to operate the activity wheel requires little human intervention and proceeds quickly. Because of the Lucite construction, an animal is visible at all times during training and testing. A brake was installed to stabilize the wheel during rest periods, or periods when other behavioral paradigms are in effect, and to prevent animals from operating the wheel at unacceptably high rates. A retractable water bottle permits access to water only during rest periods. Finally,

additional behavioral paradigms can be utilized by installing pressplates, visual and auditory cues, etc., on one of the stationary sides of the wheel.

Requiring an animal to operate the activity wheel, as opposed to motorized operation, is particularly advantageous in situations where the experimental procedures are known to cause a decrement in physical performance. In addition to the fact that rate changes generated by an animal can be used to evaluate physical capacity at any given point in time, the chance of injury is minimized should an animal stumble or fall during training.

II. DESIGN OF THE ACTIVITY WHEEL

Activity Wheel. A diagram of the activity wheel appears in Figure 1. Basically, it consists of two 48-inch diameter rings of 1/2-inch Lucite held together with 120 aluminum bars 3/8 inch in diameter and 24 inches long. The inside diameter of the rings is 40 inches and the bars are set into the rings on a 46-inch diameter circle. This cage assembly rests on four 4-inch rollers that have a groove 1/4-inch deep and wide enough to accept the Lucite rings without binding. The rollers are mounted on ball bearings on two shafts spaced 24-1/4 inches from center to center. These shafts are mounted on a 1-inch thick Lucite base 36 inches wide and 51 inches long. There are four 2-inch rollers at the top of the assembly which do not normally touch the rings. They are close enough, however, to prevent the wheel from leaving the grooves of the lower rollers. By test, a 1/2-pound pull was required on the tangent to initiate rotation of the wheel. The sides are 50 by 51 inches and are made of 5/8-inch Lucite. They are stationary and are attached to the base so that there is a 1/4-inch clearance between the sides and the rotating cage.

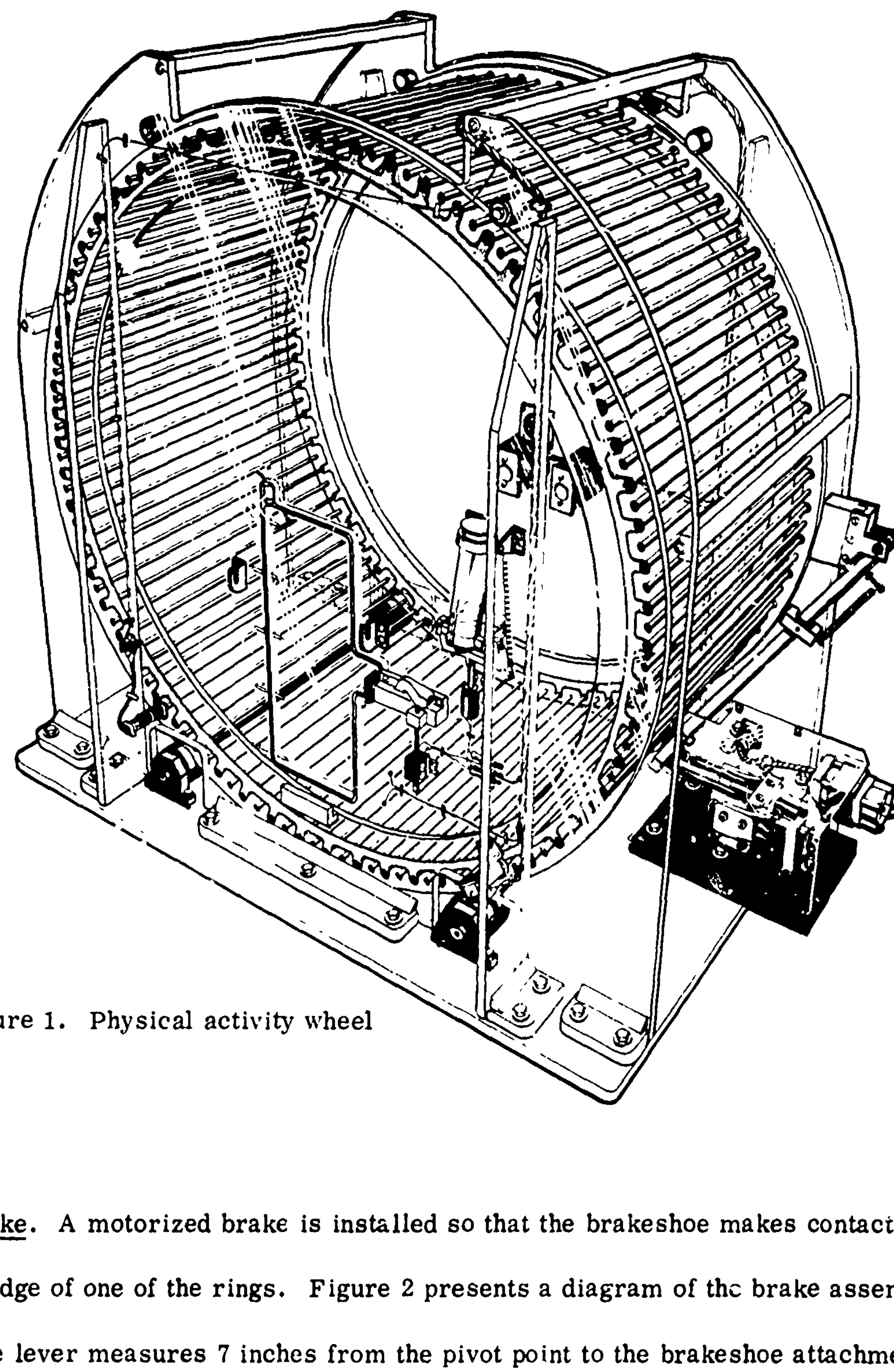

Figure 1. Physical activity wheel

Brake. A motorized brake is installed so that the brakeshoe makes contact with the edge of one of the rings. Figure 2 presents a diagram of the brake assembly. The brake lever measures 7 inches from the pivot point to the brakeshoe attachment and 14 inches from the pivot point to the motor attachment. It is connected to the nut

on the lead screw by two coil springs. The lead screw and nut have 20 threads per inch. The brake motor is a Dayton model 3M153, 20 rpm, 1/100 hp, 115 V, 60 Hz, reversible split-phase capacitor gearmotor. Adjustable microswitches are provided to limit the travel to approximately 1 inch and to provide an indication on the control panel of the brake position.

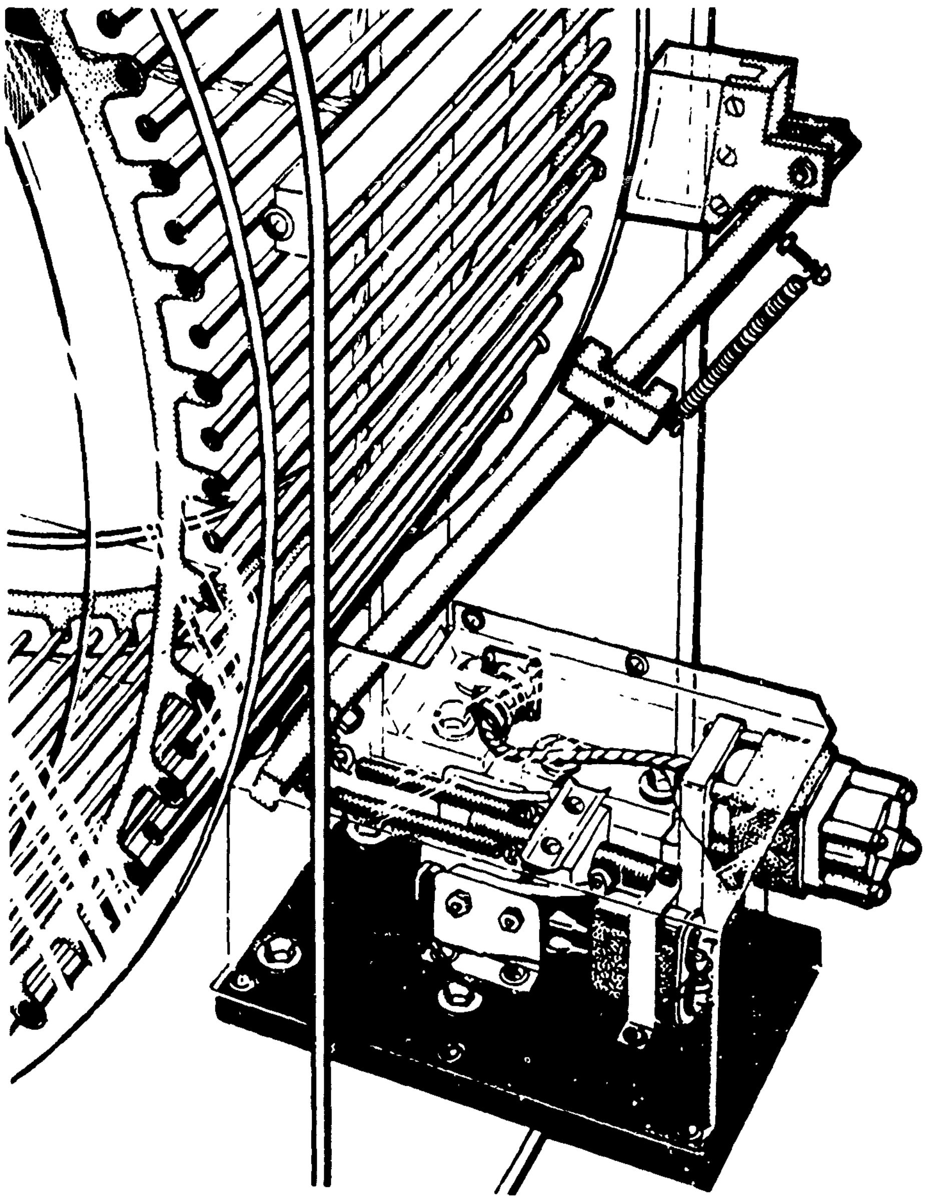

Figure 2. Brake mechanism

Shock grid. A ring of 1/32-inch aluminum is fixed to the outside of each of the Lucite rings. These aluminum rings are connected to alternate bars to provide shock as an aversive stimulus to the subject. Spring loaded carbon wheels are attached to each side and make contact with the aluminum rings. A microswitch is installed at the top with a cam on one of the rings so that the switch will close once for each revolution of the wheel. A magnetic pickup for the tachometer (see description under IV. Control Panel) is installed on one of the sides so that it is adjacent to the screws that hold the bars. Steel screws were used on this side to trigger the magnetic pickup.

Other equipment. A spring loaded door is provided on one side with a solenoid operated latch. A primate transfer box can be fitted over this door. Shock connections are provided for the transfer box to force the subject to enter the wheel if necessary. A solenoid-operated retractable water bottle is mounted on the door side of the apparatus and is automatically withdrawn while the subject is rotating the wheel. A 2-1/4-inch 3.2-ohm speaker is mounted on the opposite side to provide auditory stimuli to the subject. Two model 10-0229-1820-L Industrial Electric Engineers one-plane readouts are mounted on the same side to provide visual stimuli. Mounted with the one-plane readouts are two model No. 8670A Grason-Stadler pressplates for subject responses during periods in which reinforcement schedules not involving rotation of the wheel are operating.

IV. CONTROL PANEL

A portion of the program control panel is shown in Figure 3. Figure 4 presents a schematic diagram of the control wiring and Figure 5 presents a schematic of the wheel wiring.

Program control panel. The program of the control panel utilizes standard relay logic modules mounted in a standard relay rack with a 28-volt dc power supply. The program stepper consists of an Automatic Electric No. RS-48V, 52-point, 8-level, 28-volt dc stepper, an Automatic Electric No. AW-42 OCS relay, and two Cherry Electric Products Corporation No. C10-54A crossbar type selector switches. Each of these switches contains 50 slides having 11 positions each. These items along with the required hardware are mounted on a standard rack panel. The OCS relay switches between two levels of the stepper so that 104 steps are obtained with a 52-step stepper. The first 100 steps are connected successively to the 100 slides of the selector switches. Each pulse at the step stud will advance the stepper to the next step thereby connecting the input stud to the next slide. The position of the slide will then determine which of the 10 output studs is connected to the input studs. The 11th position of each slide is the off position. Steps 101 through 104 of the stepper are connected directly to output studs 101 through 104. Dialight Corporation digital readouts are provided to indicate the position of the stepper and the active output. Push buttons are provided to advance the stepper and to reset it manually. An electric reset is also provided.

Tachometer. The tachometer is an Airpax Electronics model FSS232 with input sensitivity and pulse shaping input circuitry options, the pickup is an Airpax No. 700-0941-A, and the meter is an Airpax No. 210. A new dial was made for the meter with two scales, one calibrated in revolutions per minute and the other in miles per hour. The switch point controls were removed from the main body of the tachometer and mounted on the panel so that they are readily available to the operator. These

controls were fitted with pointer knobs and dials calibrated in miles per hour. Three pilot lights were also provided to indicate when the wheel is operated at a speed greater than the set points.

Brake control. The brake control is mounted on the same panel as the tachometer. It consists of a relay to control the brake motor, a toggle switch to operate the brake manually, and four pilot lights to indicate the action and position of the brake. The pulse generator was constructed using Amperite thermostatic flashers as the basic units. These flashers have a time cycle of approximately 1/3 on and 2/3 off and are available in five increments from approximately 30 pulses per minute to 90 pulses per minute.

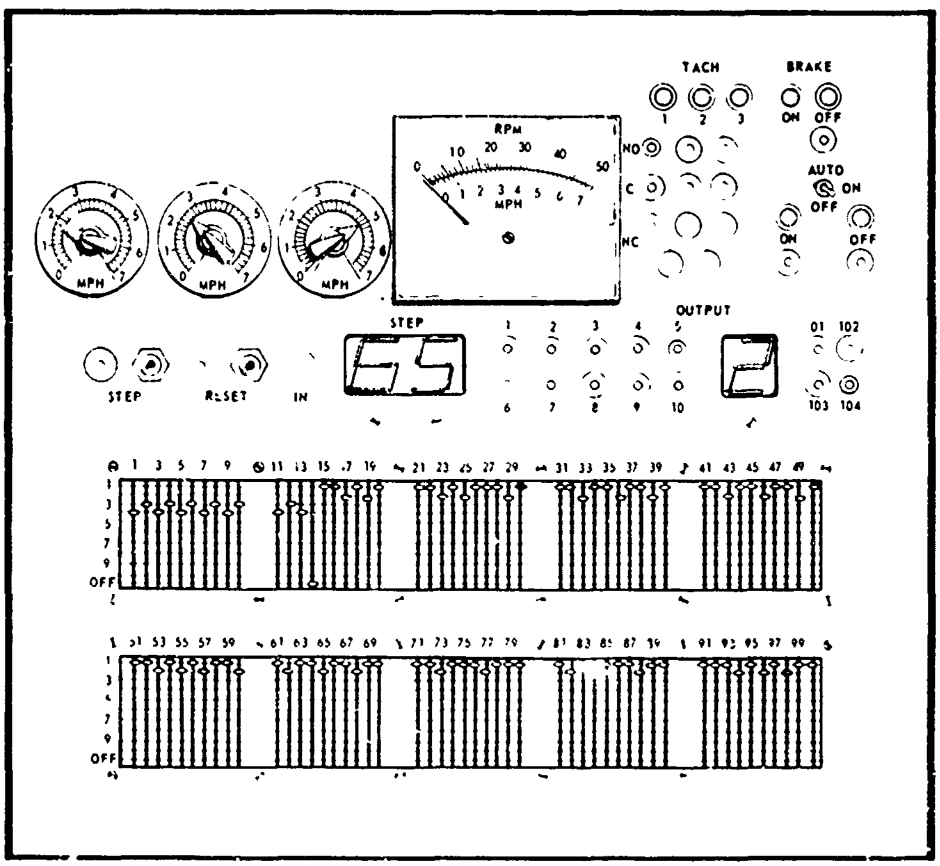

Figure 3. Program control panel

Program operation. Switch No. 1 in Figure 4 is a master switch and can be used to turn off the program at any time without turning off the power to the rack. Switch No. 2 is a three-position toggle switch. It is off when the handle is in the center position. When the handle is up, water is presented to the subject, and when it is down, the door on the wheel is unlatched. Switch No. 3 is also a three-position switch. When the handle is up, the shock is controlled automatically during the activity period, and when it is centered, the shock is off during the activity period. When the handle is down, the shock will be on provided the wheel is turning at a speed that is less than the setting of the switch point No. 1 control on the tachometer. Switch No. 4 is a two-position toggle switch. When the handle is up, the output of the shock power supply is directed to the wheel, and when it is down, the shock is directed to the transfer box. Switch No. 5 is a training aid for the behavioral testing portion of the program. If it is on, the subject will receive shock as an aversive stimulus for either an incorrect response or for failure to respond. If it is off, the subject will be shocked only for failure to respond.

Relays K1 through K7 are connected to positions 1 through 7 of the program stepper. Relay K1 will light a square on the left one-plane readout and a circle on the right one-plane readout. Relay K2 will light a square on the right and a circle on the left. Relay K3 will light an amber light on the left and relay K4 will light an amber light on the right. Relays K5 through K7 are spare relays that can be used to add additional cues. The variable resistance in series with the D contacts of relays K1 through K7 is a training aid for reducing the intensity of the visual cues controlled by these contacts. Contacts F and H of relays K1 through K7 are used to decode the

responses of the subject for correct and incorrect responses. Relay K8 operates when a correct response is made and relay K9 operates when an incorrect response or an omission occurs.

The two pulse formers are used to produce one discrete pulse each time the subject presses a manipulandum. Counters are provided to register the number of correct and incorrect responses as well as the number of omissions. A graphic record of this information is also obtained on a Gerbrands cumulative recorder.

If the active slide on the program stepper is in any of the positions 1 through 7, the No. 1 clock will run. This clock determines the length of each behavioral trial and advances the stepper when it times out. The No. 2 clock determines the length of the visual cue, the No. 3 clock determines the length of the tone, and the No. 4 clock determines the length of the shock. Shock can also be pulsed by turning on the pulse stream generator. An interval timer is provided to record the cumulative response time of the subject's trial by trial responding.

If the active slide of the program stepper is in the No. 8 position, the No. 5 clock will run. This will activate the activity portion of the program. At the beginning of this period, the brake will be full on and will start moving to the off position. When it moves to full off, switch No. 204 (see Figure 5) will turn on relay K10. K10 will stay on until clock No. 5 times out. Shock is withheld until relay K10 is activated. This delay provides the animal with an opportunity to accelerate the wheel to a safe speed without being immediately shocked. After relay K10 is turned on (assuming switch No. 3 is in the up position), shock will be delivered to the subject if he is turning the wheel at a speed that is less than the setting of switch point No. 1

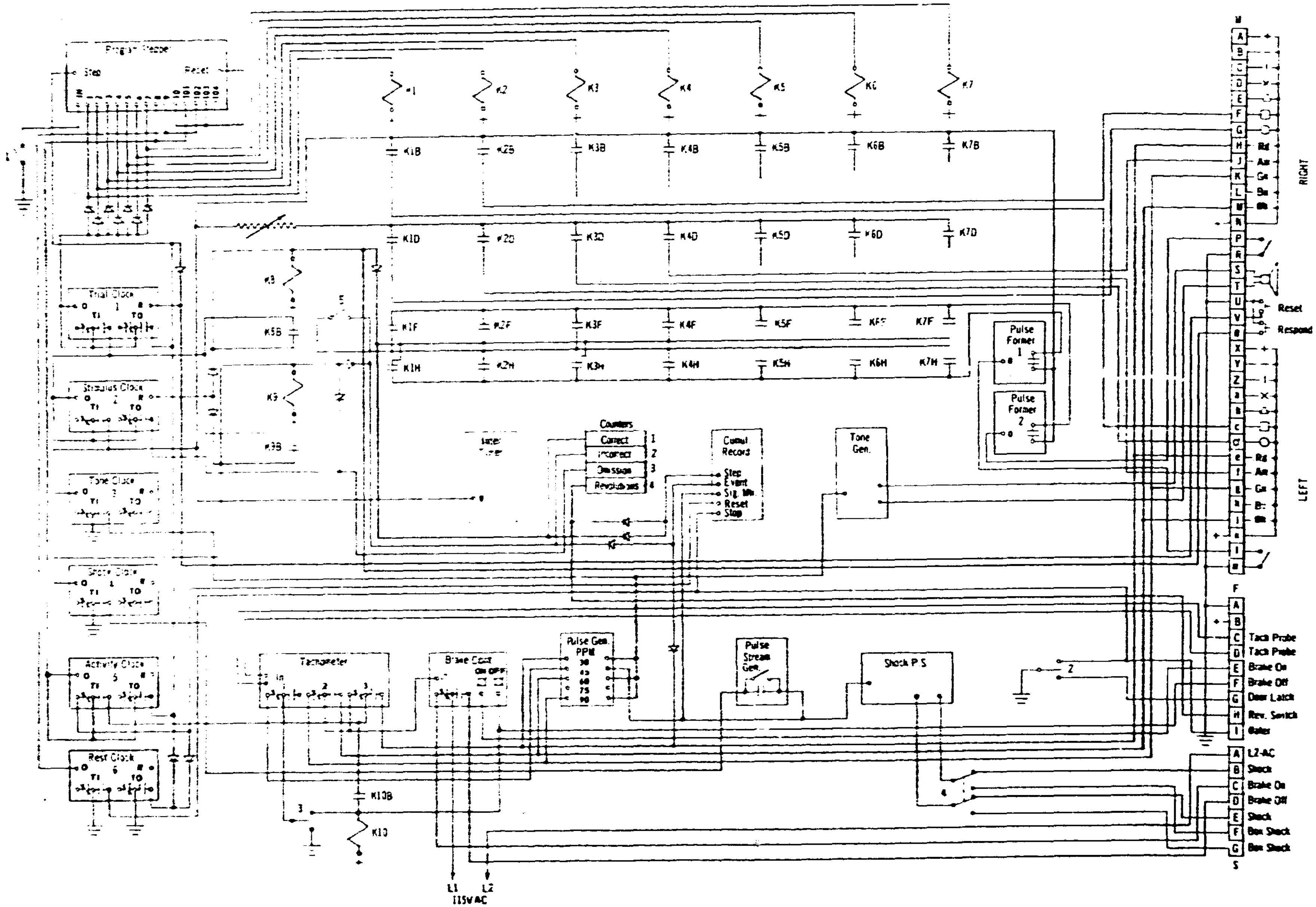

Figure 4. Wiring diagram for the program control

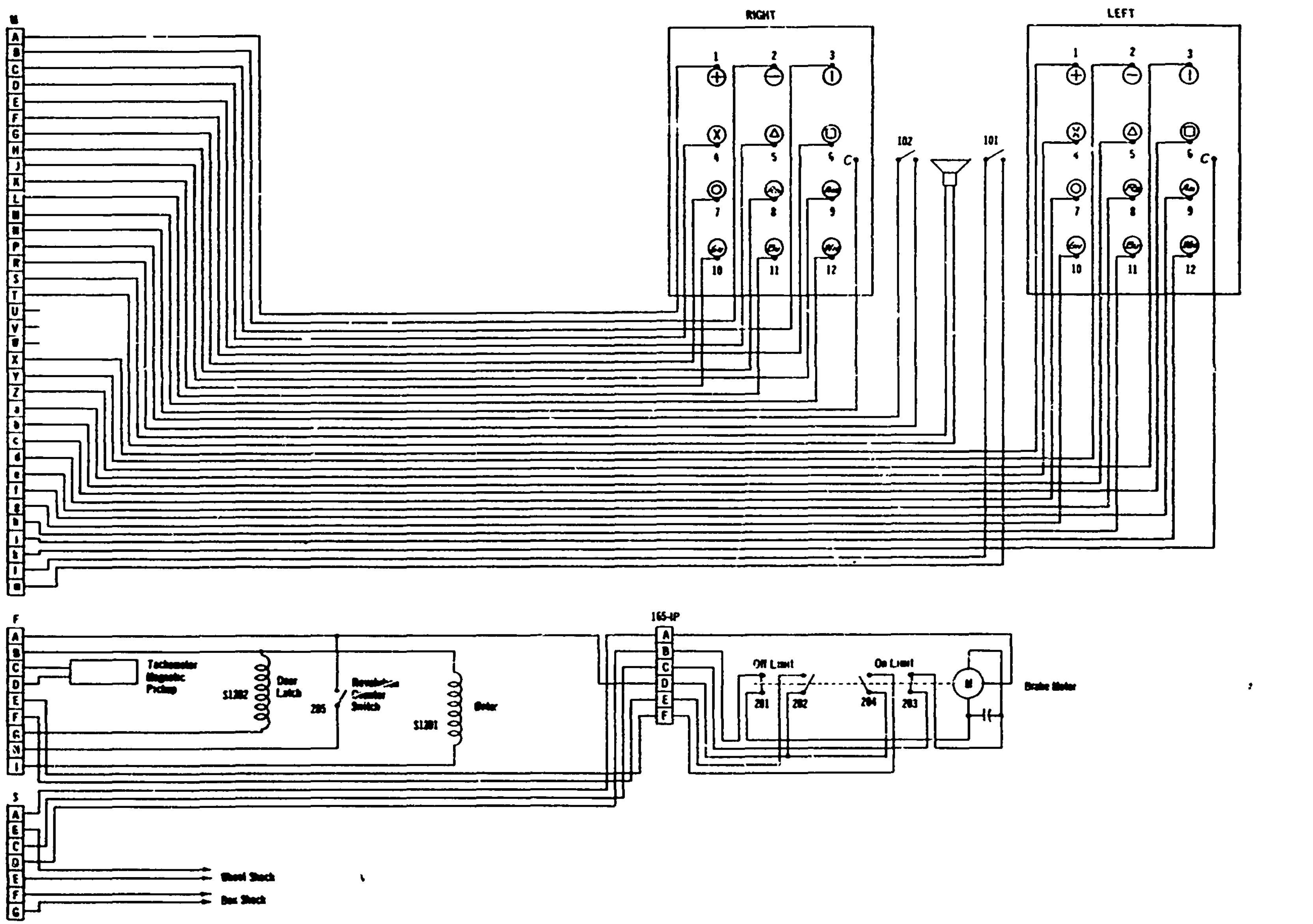

Figure 5. Wiring diagram for the activity wheel

on the tachometer. This shock is pulsed approximately 45 times per minute by the pulse generator. Shock is on 0.4 second and the shock to shock interval is 0.9 second. The length of the shock to shock interval permits the subject to accelerate the wheel sufficiently to escape the shock. The shock power supply has a 60-Hz ac output and the intensity can be controlled from 0 to 10 mA. The shock is turned off by the tachometer as soon as the subject turns the wheel at a speed greater than the setting of switch point No. 1.

If the subject is turning the wheel at a speed that is less than the setting of switch point No. 2 of the tachometer, both of the one-plane readouts will show a green light and the tone in the speaker will be interrupted 90 times a minute by the pulse generator. As soon as the subject turns the wheel at a speed that is greater than the setting of switch point No. 2, the readouts will show a white light and the tone will be interrupted 60 times a minute by the pulse generator. Switch points Nos. 1 and 2 may be set at the same speed or switch point No. 1 may be set lower to provide a speed range which is below acceptable levels but above the activation of shock. In this manner, an animal may be given cues (light, tone, and speed) to slow rotation rate before shock is applied.

If the subject operates the wheel at a speed greater than the setting of switch point No. 3, the readouts show red lights and the tone is interrupted 30 times a minute by the pulse generator. Also, the brake motor will start to apply the brake. The brake will continue to be applied until enough drag is placed on the wheel to slow it down or the subject slows down. In either case, when the wheel slows to a speed that is less than the setting of switch point No. 3, the lights will change to white, the tone will be interrupted 60 times a minute, and the brake motor will start to release

the brake. When clock No. 5 times out it will step the stepper and the motor will drive the brake full on ending the exercise session.

Each revolution of the wheel is counted on counter No. 4 and is recorded graphically on the cumulative recorder. Since the diameter of the surface the subject is running on is 45.625 inches, the circumference is 143 inches or 11.9 feet. This is the distance the subject will run for each revolution of the wheel. This distance is also equal to .00226 mile. One revolution per minute is equal to .136 mph.

If the active slide of the program stepper is in position 9, clock No. 6 will run. This is the rest period during which no cues are presented to the subject and the brake is full on. If the active slide of the program stepper is in position 10, the stepper will reset to position 1. It should be noted that step 101 of the program stepper is electrically the same as position 8 of a slide, step 102 is the same as position 9, and step 103 is the same as position 10. This allows the operator to program the control panel to present 100 trials of a behavioral program to the subject and follow it by an activity period and a rest period. After the rest period, the program stepper will automatically reset and the total program will be repeated. The program may be set up in any other desired sequence by positioning the slides accordingly. If any slide is placed in the off position, the entire program will stop when the stepper reaches that point.

V. SHAPING AND MAINTENANCE OF ACTIVITY

Current research programs in this laboratory have utilized a free-operant avoidance paradigm accompanied by visual and auditory exteroceptive cues. There were two primary reasons for utilizing these cues or control stimuli: they speed the acquisition of appropriate levels of exercise; and, once steady-state behavior is

achieved, serve to minimize the probability that an animal will actually receive an electrical shock during testing.

The following is a description of the exercise control paradigm currently in use. If an animal operates the activity wheel above a predetermined minimum rate, the shock may be avoided indefinitely. If at any time the animal fails to operate the activity wheel or rotates it below the minimum rate for shock avoidance, the exteroceptive cues change and 0.4-second shocks are presented every 1.3 seconds. As soon as the animal increases the rate of rotation until it falls into the acceptable range, the exteroceptive cues indicate appropriate behavior and shock is terminated. If the animal operates the wheel above the maximum acceptable rate, the cues change and the brake is progressively engaged until the rate of rotation again falls into the acceptable range. The brake is then released. Overspeed is never accompanied by shock.

Each animal is initially given a 2-hour orientation period in the activity wheel with the brake released. To begin shaping a steady rate of rotation, the activity lower limit dial (set point No. 1) is positioned so that any movement of the wheel is sufficient to postpone shock. Session length is limited to 2-minute periods separated by 5-minute rest periods. A day's training generally consists of six to eight activity sessions. Since a low level shock is more likely to motivate an animal to move than to freeze, and any movement eliminates the shock, monkeys typically learn to rotate the wheel early in their first day of training.

Movement of the wheel by an animal quickly evolves into rotation in a single direction. Although the wheel can be operated in either a clockwise or counterclockwise direction, animals seldom change direction once rotation of the wheel has been

established. The minimum acceptable rotation speed and session length are then slowly increased as an animal's ability to sustain longer activity levels at higher rates improves. The average training time in this laboratory to achieve stable 3 mph exercise for six or more 10-minute sessions on a daily basis has been approximately 5 weeks.

The cumulative record in Figure 6 presents the exercise record for an animal with the avoidance schedule adjusted so that the upper and lower activity limit dials were set at 3 and 6 fps respectively. The animal's mean rate of rotation is 4.3 fps or approximately 3.2 mph. For a total of 60 minutes running time, the distance traveled was 3.2 miles. Note the absence of shocks and the steady rotation rate within and between sessions. Fatigue effects manifest themselves in slight decreases in rotation rate at the end of each session and a small decrease in total revolutions per session across the day's training period. The magnitude of these fatigue effects presents a good objective measure of the degree to which an animal has become able to maintain a given level of exercise or exercise stress.

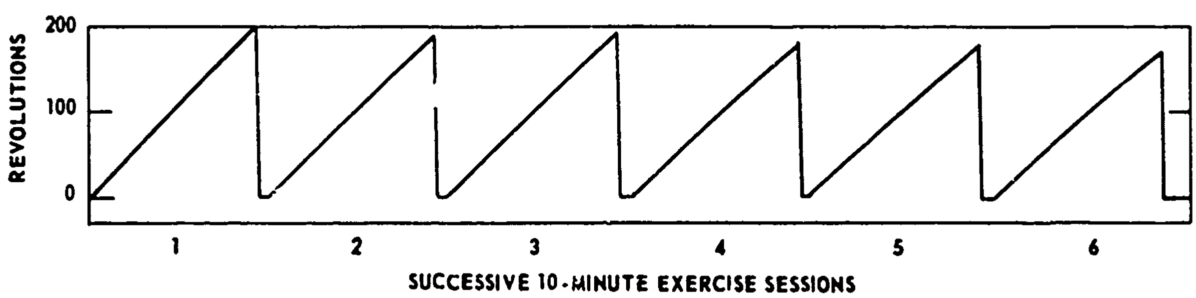

Figure 6. Cumulative record of an animal's exercise for a period of 85 minutes; 10-minute periods of activity were separated by 5-minute rest periods

REFERENCES

1. Jette, M. J., Windland, L. M. and O'Kelley, L. I. An inexpensive motor-driven treadmill for exercising small laboratory animals. J. Appl. Physiol. 26:863-864, 1969.

2. Kimeldorf, D. J. The measurement of performance in small laboratory animals. In: Performance Capacity, pp. 99-112, Spector, H., Brožek, J. and Peterson, M. S., editors. Washington, D. C., National Academy of Sciences-National Research Council, 1961.

3. Sidman, M. Avoidance behavior. In: Operant Behavior: Areas of Research and Application, pp. 448-498, Honig, W. K., editor. New York, N. Y., Appleton-Century-Crofts, 1966.

4. Skinner, B. F. The measurement of "spontaneous activity". J. Gen. Psychol. 9:3-23, 1933.